REMARKS

Claims 1 through 23 continue to be in the case.

Claims 1 through 23 are allowed.

The Office Action of March 16, 2004 states that this application is in condition for allowance except for the following formal matters:

Thc disclosure is objected to because of the following informalities: Reference is made to specific claims throughout the claims***.

Thc disclosure is objected to because of the following informalities: the specification improperly makes reference to claims to describe the invention (for example, lines 6 and 9, page 1), applicant is advised to dclcte all reference to claims and incorporate the claims by rewriting them in the specification. Appropriate correction is required.

Applicants comply with the above-stated requirements and provide a Substitute Specification in which references made to specific claims have been removed. The applicants also enclose a marked-up copy of the Substitute Specification.

The Office Action continues that the applicant is reminded of the proper language and format for an abstract of the disclosure. The abstract should be in narrative form and

generally limited to a single paragraph on a separate sheet within the range of 50 to 150 words. It is important that the abstract not exceed 150 words in length since the space provided for the abstract on the computer tape used by the printer is limited. The form and legal phraseology often used in patent claims, such as "means" and "said," should be avoided. The abstract should describe the disclosure sufficiently to assist readers in deciding whether there is a need for consulting the full patent text for details. The language should be clear and concise and should not repeat information given in the title. It should avoid using phrases which can be implied, such as, "The disclosure concerns," "The disclosure defined by this invention," "The disclosure describes," etc.

Applicants appreciate the kind suggestions of the Examiner and enclose the Abstract of Disclosure in compliance with the above-stated requirements.

The Office Action states that claims 1-23 allowed. As to claims 1-8 and 13-20, the prior of record, taken alone or in combination fails to disclose or render obvious an apparatus for non-contact three-dimensional measurement of bodies consisting of a turntable to receive a body and an optical triangulation sensor wherein said body is located on the turntable in a system of coordinates determined, one the one hand, by at least two parallel lines or body edges with a known spacing and angles of the turntable and, one the other hand, by at least two measuring points at known distances from a center and known displacement of the triangulation sensor between these measuring points, in combination with the rest of the limitations of claims 1 and 13 respectively.

Applicants appreciate the fact that the prior of record fails to disclose or render obvious the present application as to claims 1-8 and 13-20.

The Office Action further states that as to claims 9-12 and 21-23, the prior of record, taken alone or in combination, fails to disclose or render obvious a method for non-contact three-dimensional measurement of bodies consisting of a turntable to receive a body and an optical triangulation sensor wherein at least two lines or body edges running parallel at a known distance are used to determine angles of turntable by rotating said lines and subsequently capturing them in the measuring spot of said triangulation sensor in a first and second position by the known dislocation, said angles being used to calculate the distance of said triangulation sensor from the center of said turntable and to further calculate the coordinates x, y of said triangulation sensor (2) relative to the turntable center (M) as coordinates of origin, in combination with the rest of the limitations of claims 9 and 21 respectively.

Applicants appreciate the fact that the prior of record fails to disclose or render obvious the present application as to claims 9-12 and 21-23.

Reconsideration of all outstanding rejections is respectfully requested.

All claims as presently submitted are deemed to be in form for allowance and an early notice of allowance is earnestly solicited.

Respectfully submitted,

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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

SUBSTITUTE SPECIFICATION
(marked-up copy)

Inventor(s): Dieter Gebauer et al.

Title: APPARATUS FOR NON-CONTACT THREE-DIMENSIONAL MEASURING OF BODIES AND METHOD FOR DETERMINING A SYSTEM OF COORDINATES FOR MEASURING POINT COORDINATES

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Description

Apparatus for non-contact three-dimensional measuring of bodies and method for determining a system of coordinates for measuring point coordinates.

This invention relates to apparatuses for non-contact three-dimensional measurement of bodies ~~according to the introductory part of claim 1~~ and methods for determining a system of coordinates for measuring points on an apparatus for non-contact three-dimensional measuring of bodies ~~according to the introductory part of claim 9~~.

The triangulation method is one of the most common methods used in range and length measurement and two- or three-dimensional contour detection. A triangulation sensor is used, and the beam from a laser diode is focused through a lens on the workpiece. It produces a bright light spot. When this light spot is viewed at a fixed angle using a position detector or camera, the place where the spot is shown moves within the image as soon as

the intersecting point of the laser beam and the workpiece are moved relative to the sensor. This displacement is measured to determine the distance of the workpiecc or its surface contour when moving perpendicular to the illuminating laser beam.

DE 43 01 538 A1 (Apparatus and arrangement for non-contact three-dimensional measuring, in particular for measuring plaster casts of teeth) uses a turntable on which the body to be measured is placed, a triangulation sensor and a data proccssing and control unit connected to it to determine the geometry of rounded parts. Measurement is based on either local calibration of each measuring head that must take into account in summary the actual position of measuring surfaces in space by coordinate transformation, or calibration of the entire measuring system using at least one calibrating body where all points in space that arc of interest are entered into a joint calibration table. Calibration cannot be avoided.

DE 44 07 518 A1 describes an apparatus and a method for non-contact measurement of three-dimensional objects based on optical triangulation. The triangulation sensor can bc moved in

one direction (y direction) and pivoted in the x plane across a preset angular position at a fixed point that can be chosen. This involves two independent movements of the triangulation sensor. The object to be measured is located on the turntable. This turntable on the one hand provides rotary movement, on the other hand it can be moved in vertical direction to the movement of the sensor using another driving mechanism. The movements of the triangulation sensor and the turntable determine the coordinates of the measuring spot of the radiation source. Tilting the triangulation sensor allows measuring most dimensions of undercuts, covered points, pocket holes and similar spots of the object. DE 40 37 383 A1 (Method for continuous contactless measurement of outlines and arrangement for carrying out the measuring procedure) uses triangulation to determine the outer contour line of a moving profile. The sensor only detects the distance to the profile and thus its contour. The measuring spot cannot be placed in a system of coordinates.

DE 195 04 126 A1 (Apparatus and method for contactless measurement of three-dimensional objects using optical triangulation), DE 197 27 226 A1 (Set-up of measuring

instruments and method for contactless measurement of the three-dimensional spatial shape of a groove in a spectacles frame), and US 5 270 560 (Method and apparatus for measuring workpiece surface topography) record the outlines of workpieces or workpiece parts to be detected step by step. The respective workpiece or workpiece part is only measured relatively.

Coordinate measurement on an object surface is carried out in DE 40 26 942 A1 (Method for contactless measurement of object surfaces) where images are recorded using a camera. This camera is mounted to an index arm of a coordinate gauging device that can be moved in three spatial directions (x and y directions and pivoting). The object to be measured is located on a turntable.

The problem of the invention ~~described in claims 1 und 9~~ is to provide easy three-dimensional measurement of the geometry of a body and to easily and correctly match triangulation measurement data with the three-dimensional geography of a body.

This problem is solved by the <u>following</u> characteristics: ~~listed in claims 1 and 9.~~

- a turntable (1) receiving a body and an optical triangulation sensor (2) with at least one radiation source, radiation detector, and an optical system. The triangulation sensor (2) is placed above said turntable (1) and can be moved along an axis using a driving mechanism so that radiation from the radiation source hits the body located on the turntable (1) in a system of coordinates. The coordinates are determined, on the one hand, by at least two parallel lines (g1, g2) or body edges with a known spacing (d) and angles (α, β) of the turntable (1) and, on the other hand, by at least two measuring points at known distances (R1, R2) from the center (M) and known displacement (c) of the triangulation sensor (2) between these measuring points, and the turntable (1). The driving mechanism and the triangulation sensor (2) are connected to a data processing and control unit;

- a turntable (1) receiving the body;

- an optical triangulation sensor (2) with at least one radiation source (3), radiation detector (4), and an optical system. The triangulation sensor (2) is placed above the turntable (1) and can

be moved along an axis using a driving mechanism so that the radiation (9) from said radiation source (3) hits said body, and;

- a data processing and control unit for turntable (1), driving mechanism and triangulation sensor (2). In the triangulation sensor (2) at least two lines (g1, g2) or body edges running in parallel at a known distance (d) are used to determine angles (α, β) of turntable (1) by rotating said lines and subsequently capturing them in the measuring spot of the triangulation sensor (2) in a first and a second position of the triangulation sensor (2) displaced from the first position by the known dislocation c. The angles are being used to calculate the distances R1, R2 of said triangulation sensor (2) from the center (M) of said turntable and to further calculate the coordinates x, y of said triangulation sensor (2) relative to the turntable center (M) as coordinates of origin.

The apparatus for non-contact three-dimensional measurement of bodies and the method for determining a system of measuring point coordinates on an apparatus for non-contact three-

dimensional measurement of bodies are characterized by particular simplicity and easy implementation. Advantageously, this makes the apparatus and method applicable in production sites for special workpieces. The design is very simple, and the method requires simple and cost-efficient set-up, which ensures a wide range of uses.

The basis of the system is an optical triangulation sensor. The beam of a laser diode is focused through a lens on the workpiece. A light spot emerges on the workpiece. This spot is recorded at a fixed angle by a radiation detector. When the workpiece moves relative to the triangulation sensor, the place where the spot is shown also moves within the image. The outline of the workpiece is determined by measuring this displacement.

Before the workpieces are measured, a system of coordinates for three-dimensional matching of the workpiece geometry is determined in a first measurement. A body with known dimensions of its edges or lines is placed on the turntable and measured during one rotation using the triangulation sensor. The body can be placed on the turntable in any position. Instead of

said body, lines can be placed onto or into the surface of the turntable.

The triangulation sensor can scan the workpiece by moving the sensor along just one axis and rotating of the workpiece. Controlled triggering of the respective driving mechanisms and use of the system of coordinates results in continuous detection of the workpiece geometry at a high measuring data rate and precision. The apparatus according to the invention is thus characterized by its minimal design. The low number of movements required, i.e. one translatory movement of the triangulation sensor and a rotational movement of the turntable, results in determining the outline of a body with a minimal error of measurement.

Advantageously, the apparatus is particularly suited for measuring rotationally symmetric workpieces. Advantageously, the method can be used to measure rotationally symmetric workpieces. Control and calculation of workpiece geometry is advantageously controlled using a computer.

Preferred embodiments: ~~of the intention are described in claims 2 to 8 and 10 and 12.~~

The apparatus is characterized in that:

The radiation source (3) of the triangulation sensor (2) is placed in such a way that the radiation from the radiation source (3) is perpendicular to the surface of said turntable (1). The triangulation sensor (2) is placed on a hinge or ball-and-socket joint above the turntable (1) and can be moved along an axis using the driving mechanism. There is at least one sensor that directly and/or indirectly measures the angle between the radiation (9) and the workpiece. At least some areas of the surface of a body that produces excessive scattering in the form of multiple reflections of the radiation (9) from the radiation source (3) are fixedly and/or removably covered by a covering body of known thickness and with low-scattering surfaces. The parallel lines or body edges of a measuring body are straight or annular on said turntable (1). A measuring body with at least two edges or a measuring body with at least two lines is placed on said turntable (1) when determining a system of coordinates only. The turntable

(1) has at least two end stops for bodies placed at a distance from each other. At least one magnet is integrated into said turntable (1).

The method is characterized in that:

The radiation source (3) of said triangulation sensor (2) is placed in such a way that the radiation from the radiation source (3) is perpendicular to the surface of said turntable (1). The parallel lines or body edges of a measuring body are arranged straightly or annularly on said turntable (1). A measuring body with at least two edges or a measuring body with at least two lines is placed on said turntable (1) when determining a system of coordinates only. The radiation source (3) of the triangulation sensor (2) is placed in such a way that the radiation from the radiation source (3) is perpendicular to the surface of the turntable (1).

The surface profile of the workpiece is detected by one perpendicular movement to the illuminating laser beam of the triangulation sensor ~~according to the improvement described in claim 2~~.